INTRODUCTION

The North Loup Division of the lower Platte River basin, an irrigation project proposed for development by the U. S. Bureau of Reclamation, is in central Valley County and in southwestern Greeley, northern Howard, northwestern Merrick, and southwestern Nance Counties, Nebr. (See fig. 1.) At the request of the Bureau of Reclamation, the Geological Survey made a study of the ground-water conditions and potentialities in the project area. This report embodies the results of that study.

Most of the fieldwork was done during the late summer of 1956 and the spring of 1957. All the irrigation wells in the area were visited and pertinent data on them were obtained, in part by visual inspection of the wells and in part by interviewing their owners or operators (table 4). Personnel of the Bureau of Reclamation assisted in making this inventory. The altitudes of the measuring points of the wells either were determined by surveyors of the Bureau of Reclamation or were estimated by the authors of this report from topographic maps of the Geological Survey. Water-level data collected during the inventory were used in mapping the depth to water and the configuration of the water table. (See pl. 1.) Chemical analyses of the water from 10 wells (table 1) were made in the Geological Survey's laboratory in Lincoln, Nebr.

This report is based not only on the information obtained specifically for this investigation but also on geologic and hydrologic data previously collected in the area. As part of the statewide program of geologic and ground-water studies made cooperatively by the U. S. Geological Survey and the Conservation and Survey Division of the University of Nebraska, 56 test holes had been drilled in or near the area. Copies of the logs of these test holes may be obtained from the Conservation and Survey Division of the University of Nebraska. Also as part of the Federal-State cooperative program, water-level measurements had been made at irregular intervals since 1934 in 2 wells in the area (table 3) and chemical analyses had been made of 14 ground-water samples (table 1) and of 1 sample of river water (table 2). As part of the program of the Interior Department for development of the Missouri River basin, water-level measurements were made at intervals in 68 wells in the area (table 3) and chemical analyses were made of 2 ground-water samples (table 1) and 11 samples of river water (table 2). Reports by Connor (1951), Miller (1951), Brown (1955), and Sniegocki (1955, 1959)--all prepared as part of the Missouri River basin development program--also contain pertinent information on the area described in this report.

This investigation was made under the supervision of G. H. Taylor, regional engineer in charge of ground-water investigations in the Missouri River basin. The quality-of-water phase of the investigation was under the supervision of P. C. Benedict, regional engineer, Quality of Water Branch.

SYSTEM FOR NUMBERING WELLS AND TEST HOLES

The well and test-hole numbers in this report indicate the location of each well and test hole according to the survey of the area by the Bureau of Land Management. The first segment of a number indicates the township, the second the range, and the third the section. The lowercase letters following the section number indicate the position of the well or test hole within the section. These letters are assigned in a counterclockwise direction beginning with "a" in the northeast quadrant. The first letter indicates the quarter section, or 160-acre tract; the second letter indicates the quarter-quarter section, or 40-acre tract. (See fig. 2.) When two or more wells or test holes are situated within the same tract, they are distinguished by numerals, beginning with 1, added after the lowercase letters.

GEOGRAPHY

Location and extent of area

The area described in this report includes about 350 square miles in east-central Nebraska. It consists of (1) the part of the upland in Valley County that is drained principally by Turtle, Dane, and Mira Creeks; (2) the North Loup River valley in Valley, Greeley, and Howard Counties; and (3) the Loup River valley in Howard, Merrick, and Nance Counties. (See fig. 1.) It is in the High Plains section of the Great Plains physiographic province, as described by Fenneman (1931, p. 11-25).

Topography and drainage

The drainage basins of Turtle, Dane, and Mira Creeks and intervening streams comprise about 250 square miles. About half this part of the report area is an elongate northwest-trending upland plain which ranges in altitude from 2,050 to 2,225 feet above mean sea level. The remainder is a highly dissected upland in which the highest ridges are about 150 feet higher than the general level of the upland plain and 250 to 300 feet higher than the flood plain of the North Loup River.

The valley floors of the North Loup and Loup Rivers are 2 to $3\frac{1}{2}$ miles wide. The Recent flood plain in each is less than half a mile wide and is bordered by terraces which are separated in some places by scarps but more generally by gentle slopes. Of the two distinct terraces that can be recognized almost anywhere along these valleys, the higher is 30 to 50 feet above stream level and in some places is as much as 2 miles wide. Along the margins of the valleys, the higher terrace merges with the steep slope that separates the valley floor from the bordering uplands.

The North Loup flows at an altitude of about 2,100 feet where it enters Valley County and at an altitude of about 1,750 feet where it joins the Middle Loup to form the Loup River. The altitude of the Loup River where it leaves the area near Fullerton, Nance County, is about 1,620 feet.

Climate

According to records of the U. S. Weather Bureau, the climate of the area is characterized by wide variations in temperature, precipitation, and wind movement.

The mean annual temperature ranges from 48° to 50°F. Usually, on several days each summer the maximum temperature is 100°F or a little higher and on several days each winter the minimum is 0°F or below. The last killing frost normally occurs in early May and the first in early October.

The amount and distribution of precipitation differ greatly from year to year. The mean annual precipitation ranges from about 21 inches at the west end of the area to about 23 inches at the east end. The greater part of the precipitation occurs during thunderstorms in the period April through September. Lack of rain in late summer occasionally causes reduced crop yields, but because the soil, if properly cultivated, is highly retentive of moisture, total crop failures are rare.

The prevailing wind is from the south and southeast during the summer and from the northwest during the winter. The average wind velocity is 9 to 10 miles per hour.

Population

The first permanent settlers in the area arrived about 1870. Many others soon followed, homesteading all the valley land and a large part of the upland. By 1890 almost the entire area had been homesteaded. The present farm population is estimated to be about 6,000.

The principal cities and villages in or near the area and their population in 1950 are listed below in downstream order:

City or village	Population
Elyria	87
Ord	2,239
North Loup	526
Scotia	474
Cotesfield	106
Elba	216
St. Paul	1,676
Cushing	71
Palmer	434
Fullerton	1,520

Transportation

Cushing and Ord are on a branch line of the Chicago, Burlington & Quincy Railroad; all the other principal cities and villages, including Ord, are on a branch line of the Union Pacific Railroad. Elyria, Ord, North Loup, Scotia, Cotesfield, and Elba are on or within a mile or two of Nebraska Highway 11; St. Paul is on U. S. Highway 281 and Nebraska Highway 92; and Fullerton is on Nebraska Highway 14. Within the area described in this report, these highways are paved. Few, if any, places in the area are farther than a mile from the nearest graveled road, which generally is on a section line.

Agriculture

Agriculture is the chief industry. The principal crops are corn, wheat, and oats, most of which are fed on the farm to cattle and hogs. Both in the valleys and on level upland areas farms range in size from 160 to 320 acres, but on the rolling and rough upland areas, where most of the land is used for grazing, they are larger. Much of the terrace land in the North Loup River valley in Valley County and a small part of that in western Greeley County is irrigated with water diverted from the North Loup River. The cropland on the southwest side of the North Loup River and northwest of the center of T. 19 N., R. 14 W., is supplied irrigation water by the Taylor-Ord Canal; that on the northeast side of the river by the Burwell-Sumter Canal; and that on the west side of the river from the southern part of T. 19 N., R. 13 W., to the northwestern part of T. 17 N., R. 12 W., by the Ord-North Loup Canal. The construction of the diversion dams and canals was financed with funds made available by the Federal Emergency Administration of Public Works. The system is maintained by the North Loup River Public Power and Irrigation District, which was organized in 1936.

The use of ground water for irrigation in both upland and valley areas is increasing at a rapid rate; in the spring of 1957 there were 115 irrigation wells in the area. Of the 106 for which the date of installation is known, the first was drilled in 1920. Eight others are known to have been drilled before 1940, 35 were drilled in the 1940's, and 62 from 1950 through early 1957.

GEOLOGY

Summary of Tertiary and Quaternary geologic history

The retreat of the Late Cretaceous sea from the interior of the North American continent exposed to subaerial erosion the sediments that had accumulated in that sea. Throughout the following Tertiary period, streams draining high mountains to the west built a broad alluvial apron out from the eastern slopes of the mountains, but not until the Pliocene epoch of the Tertiary period did the alluvial apron extend far enough to bury the area described in this report. It is not certain that all the area was buried--the lack of deposits of Tertiary age in the eastern part of Nance County could indicate either that the eastward-thinning alluvial apron never reached that far or, if it did, that subsequent erosion removed it.

During the first half of the succeeding Pleistocene epoch of the Quaternary period, continental ice sheets twice advanced well into eastern Nebraska, almost reaching the area described in this report. The glaciers dammed the streams that were flowing eastward down the gentle slope of the alluvial apron, causing them to fill their valleys and, in places, to mantle the intervening uplands with the gravel and sand they could transport no farther. After both the glacial advances, silt and clay of fluvial and eolian origin were deposited over the sand and gravel, but then part, and in places all, of the Pleistocene sediments were removed by stream erosion. Although the later continental ice sheets did not advance near enough to the area to block drainageways, the regimen of the streams was so changed from time to time that valley filling repeatedly alternated with valley cutting. Wind-deposited silty clay (loess) is an important component of the mass of Pleistocene deposits.

The upland area that the Bureau of Reclamation proposes for irrigation is a topographic feature known locally as Mira Valley (also as Myra Valley). This broad valley appears to have been formed by a stream, possibly the ancestral North Loup River, that flowed southeast and east across Valley County in middle Pleistocene (Illinoian?) time. The valley areas that now are irrigated or are proposed for irrigation are stream-built terraces in a valley that was cut probably in late Pleistocene (Wisconsin) time.

Geologic formations of Tertiary and Quaternary age

The following description of the geologic formations of Tertiary and Quaternary age is based on reports by Condra and Reed (1943), Condra, Reed, and Gordon (1950), and Miller (1951) and on the logs of test holes drilled by the Conservation and Survey Division of the University of Nebraska in cooperation with the U. S. Geological Survey.

Tertiary system

Ogallala formation.--The Ogallala formation of the Pliocene series is the only formation of Tertiary age underlying the area. It consists of interbedded hard and soft layers of sandy gravel, sand, silt, and clay. Some layers are cemented by calcium carbonate, but others are relatively unconsolidated. The formation also contains minor amounts of marl, volcanic ash, and opaline sandstone resembling quartzite. Gradations, both laterally and vertically, from one lithologic type to another within short distances are characteristic of the formation. In general, the grain size of the Ogallala decreases eastward. Some beds in the Ogallala formation are so like some of the Quaternary deposits that it is not always possible to determine, when drilling, the exact depth at which the bit first enters the Ogallala formation. Generally, the first cemented bed encountered is considered to be the top of the Ogallala.

The greatest thickness of the Ogallala formation in the area described in this report is not known. Because the Ogallala was deposited on an uneven surface and was eroded deeply after it was deposited, its thickness varies considerably within short distances. An oil test (No. 1 Valla) drilled by the Shell Oil Co. in the $NW\frac{1}{4}NW\frac{1}{4}NE\frac{1}{4}$ sec. 6, T. 19 N., R. 16 W., reached Cretaceous bedrock at a depth of 812 feet. If it is correct to assume that the thickness of the Quaternary deposits at this site is no more than 100 feet and that the Ogallala thins eastward, then the greatest thickness of the Ogallala in this area is approximately that at the test well--a little more than 700 feet. Cretaceous bedrock was reached at a depth of 495 feet in an oil test (No. 1 Williams) drilled by Henry Bredthauer in the center of the $NW\frac{1}{4}SW\frac{1}{4}$ sec. 29, T. 18 N., R. 13 W. Test holes drilled in Valley County as part of the Federal-State program did not completely penetrate the Tertiary rocks, but several drilled in the North Loup River and Loup River valleys downstream from Valley County did reach Cretaceous bedrock. One in Howard County (16-11-33aa) penetrated about 270 feet of material considered to be the Ogallala. East of Howard County the Ogallala apparently is discontinuous, as several test holes in or near the Loup River valley penetrated no material believed to be of Tertiary age.

Miller (1951) mapped numerous isolated exposures of the Ogallala formation in Valley County. The most conspicuous of these are along the North Loup River valley in the eastern part of the county, both near stream level and in high bluffs on the valley wall. The Ogallala is exposed also in ravines and along the bluffs bordering Mira Valley and in several places along the North Loup River valley in Greeley and Howard Counties. The exposures consist principally of cemented beds, which commonly are referred to as "mortar beds."

Quaternary system

A generalized section of Quaternary deposits recognized in east-central Nebraska west of the till border is given below:

Series	Stage	Formation or deposit
Recent		Alluvium, colluvium, dune sand, and loess
Recent and Pleistocene		Bignell loess
Pleistocene	Wisconsin	Unnamed deposits of sand and gravel, Peorian loess, and Todd Valley sand
	Illinoian	Loveland loess and Crete formation
	Yarmouth	Sappa formation, including Pearlette ash member
	Kansan	Grand Island formation
	Aftonian	Fullerton formation
	Nebraskan	Holdrege formation

Deposits corresponding to most of those listed in the table above have been identified tentatively in the report area. However, more test drilling must be done before the age relationships of all deposits of Quaternary age can be worked out in detail.

Holdrege formation.--When the advancing Nebraskan glacier dammed the eastward-flowing streams in Nebraska, it caused the streams to aggrade their valleys and the adjacent uplands with sand and gravel. This deposit has been named the Holdrege formation. In his mapping of Valley County, Miller (1951) did not identify any exposed sand and gravel as Holdrege, nor has the Nebraska Geological Survey definitely recognized it in test holes drilled in Valley County or elsewhere in the area described in this report. A concealed deposit of sand and gravel directly overlying the Ogallala in parts of Howard and Greeley Counties outside the report area has been identified as the Holdrege (Sniegocki, 1959), so it is not impossible that remnants of the formation are concealed beneath the upland surface of Valley County also.

Fullerton formation.--The Fullerton formation, of Aftonian age, is composed of fine sand, silt, and calcareous clay deposited during the waning phase of the Nebraskan glaciation. It is considered to be of aqueous and eolian origin. After its deposition it was subjected to deep weathering, soil development, and erosion; in places a layer of peat accumulated on its surface. The Fullerton is 20 feet thick in its type exposure 1 mile northwest of the town for which it was named, just outside the report area. As is true of the underlying Holdrege formation, its extent beneath the area is unknown.

Grand Island formation.--The advance of the Kansan ice sheet into Nebraska again resulted in the blocking of eastward-flowing streams and aggradation of their valleys and adjacent uplands. The sandy gravel thus deposited is the Grand Island formation. It is composed predominantly of particles of quartz and orthoclase feldspar; mica, quartzite, and chlorite are minor constituents. The thickness of the Grand Island ranges from less than 1 foot to about 20 feet in the exposures where it could be measured within the report area. On his geologic map of Valley County, Miller (1951) shows many isolated exposures of the Grand Island formation in ravines cut by streams into the sides of Mira Valley.

Sappa formation.--The Sappa formation, of Yarmouth age, is a gray to greenish-gray silty clay which conformably overlies the Grand Island formation in many places. Within the formation is a discontinuous layer known as the Pearlette ash member; it represents accumulations of volcanic ash in lakes and ponds. Like the Fullerton, the Sappa is of aqueous and eolian origin and was subjected to deep weathering, soil formation, and erosion soon after it was deposited. Like the underlying Grand Island formation, it is exposed in several of the ravines cut by streams into the sides of Mira Valley.

Crete(?) formation.--If, as has been suggested previously, Mira Valley was formed by a stream that flowed southeastward across Valley County in middle Pleistocene (Illinoian?) time, the deposit of sand and fine gravel that underlies that valley and rests unconformably on the Ogallala formation probably is the Crete formation, which was originally described by Condra, Reed, and Gordon (1947, p. 22). The presence of this deposit was revealed by the drilling of test holes 18-13-31cb, 18-15-14cb, 18-15-2dd, and 19-14-31bb, in which the thickness of the gravel ranged from 17 to 41 feet.

Loveland loess.--After the Crete(?) formation was deposited, the entire area was blanketed by wind-deposited clayey silt (loess), which in the then-existing valley areas was reworked by running water. It commonly is light pinkish brown to reddish brown, and its original surface, where preserved, is marked by a fossil soil. Although it probably underlies much of the upland part of Valley County, it is exposed only where streams have cut ravines through the overlying Peorian loess. Many such outcrops were mapped by Miller (1951). In parts of the report area the Loveland directly overlies the Ogallala formation, but elsewhere it rests on one or another of the earlier Pleistocene formations. The thickness of the Loveland in the report area probably is nowhere more than about 20 feet.

Todd Valley sand.--The North Loup and Loup Rivers probably have been flowing in their present valleys since early in the Wisconsin stage of glaciation. The depth to which they had cut their valleys before they partly refilled them with the Todd Valley sand (originally described by Lugn, 1934, p. 324, 349-350) is not known because later erosion in these valleys removed all, or nearly all, evidence of early Wisconsin deposition. Possibly detailed geologic studies would reveal the presence of loess-buried remnants of the Todd Valley sand along the valley walls above the general level of the higher terrace in the valleys.

Peorian loess.--Deposition of the Todd Valley sand in the valleys was followed by the deposition of another widespread layer of loess, the Peorian. Throughout the upland area this layer of wind-deposited yellowish-gray silt rests directly on the weathered Loveland loess, but in the valleys of the North Loup and Loup Rivers it was removed when the rivers later cut to a deeper level. The Peorian loess, as mapped by Miller (1951), also includes the Bignell loess (originally described by Schultz and Stout, 1945, p. 241). In the report area the Peorian loess (not including the Bignell) averages about 15 feet in thickness but in some places it is as much as 50 feet thick.

Deposits of middle and late Wisconsin and Recent age.--During the middle part of the Wisconsin stage of glaciation, the North Loup and Loup Rivers deepened their valleys, removing all, or nearly all, the previously deposited Wisconsin valley fill. They then partly refilled their valleys with sand and gravel, and another layer of loess, the Bignell, was deposited. Because the Bignell loess mantles the sand and gravel that underlies the principal terrace in the valleys, it can be readily identified there. In the upland area, however, where its deposition continued into Recent time, it can be distinguished from the underlying Peorian loess only where evidence of pre-Bignell soil development on the Peorian surface has not been completely removed. In late Wisconsin time, the North Loup and Loup Rivers deepened their valleys by cutting into and through the middle Wisconsin sand and gravel. As these deeper valleys were much narrower than the earlier ones, broad remnants of the middle Wisconsin sand and gravel were left intact. The narrower valleys were alluviated in late Wisconsin time, and in Recent time even narrower valleys were cut into the late Wisconsin deposits, remnants of which form the low terrace bordering the present flood plain. The valley fill underlying the flood plain probably is not more than 15 to 20 feet thick. It is not known how much of the valley fill beneath the flood plain is undisturbed late Wisconsin sand and gravel and how much was deposited in Recent time.

GROUND WATER

Below a surface known as the water table, the deposits of Tertiary and Quaternary age are saturated with water. It is water from these deposits that is brought to the surface when wells are pumped, and, in places where the water table is close to the land surface, it is this water that keeps vegetation green during periods of drought. Also, it is the natural discharge of this water into the North Loup and Loup Rivers that largely maintains their flow when there is little or no overland runoff. In the area described in this report, water moves freely through deposits of